# Recent advances in Mask Blank Deposition and Defect Reduction

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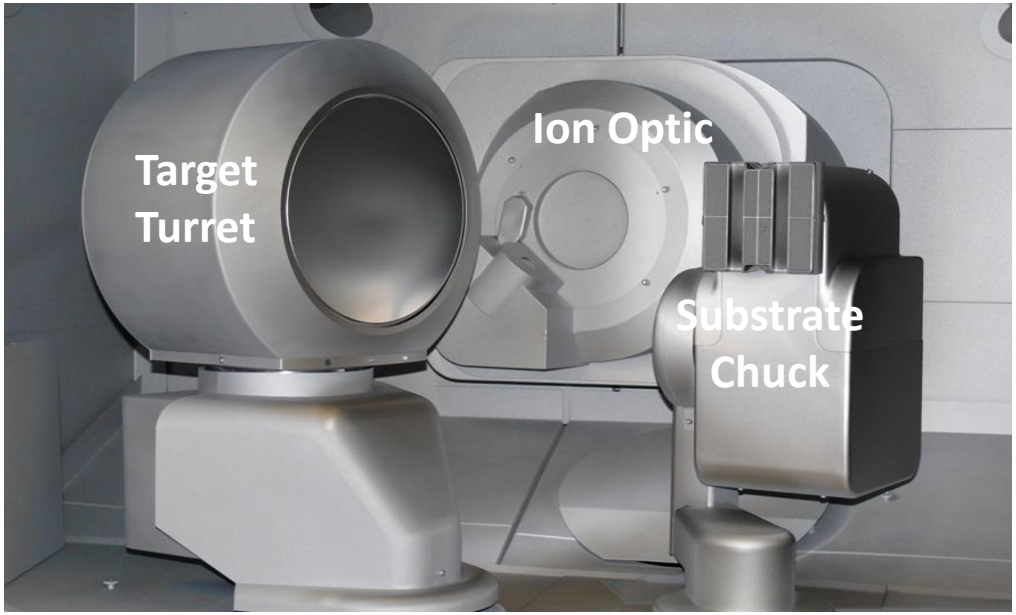
# Key Defect Challenges for EUV HVM Mask Blanks

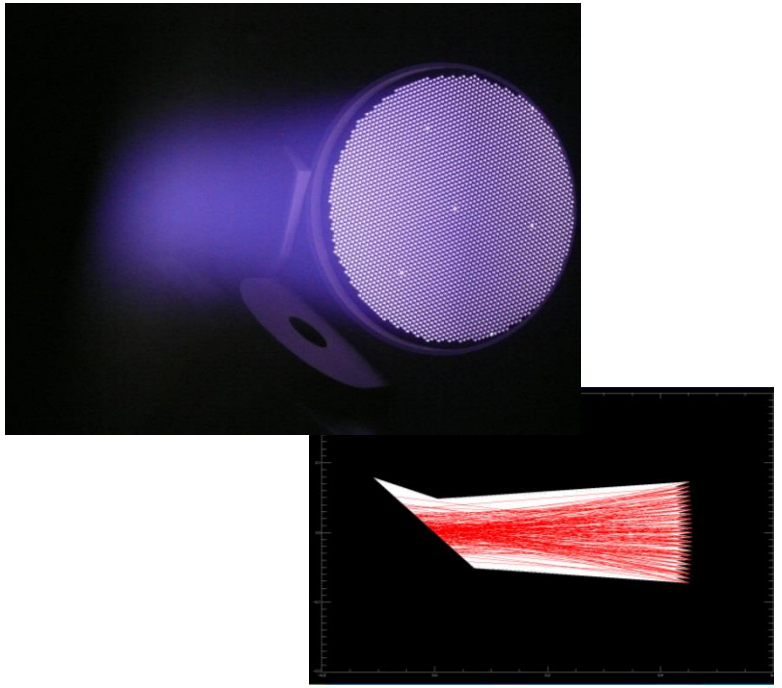
- Mask Defect Density
  - Mask Blank Defects > 80nm*
    - No defects > 80nm
    - Impacts yield of useable mask blanks and pattern masks
    - Majority are deposition defects
  - Mask Blank Defects < 80nm*
    - Limited counts are needed to enable mitigation
    - Typically substrate or surface defects which become decorated during deposition
  - Implementation of Mitigation Strategies
    - Feature level OPC
    - Pattern shift
    - Defect Repair
    - etc ,,,

* $SiO_2$ equivalent

# Mask Blank ML Deposition

*Veeco Nexus IBD Tool*

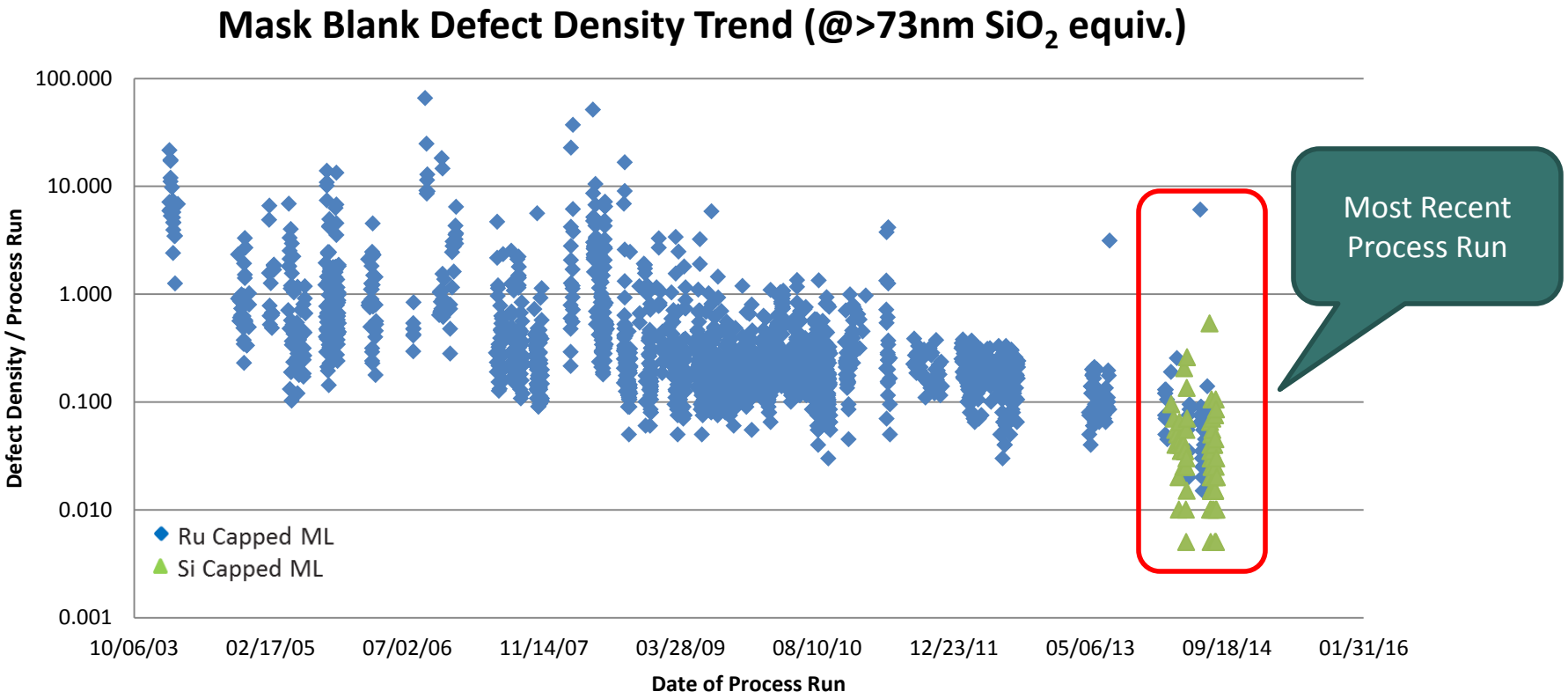


- Ion Beam Deposition (IBD)
  - The leading technology for deposition of mask blank Si/Mo multilayers
  - Only technology used by mask blanks suppliers
- Recent deposition results at SEMATECH have now confirmed IBD can achieved defect level required to support HVM

# IBD Defect Trend [2003- present]

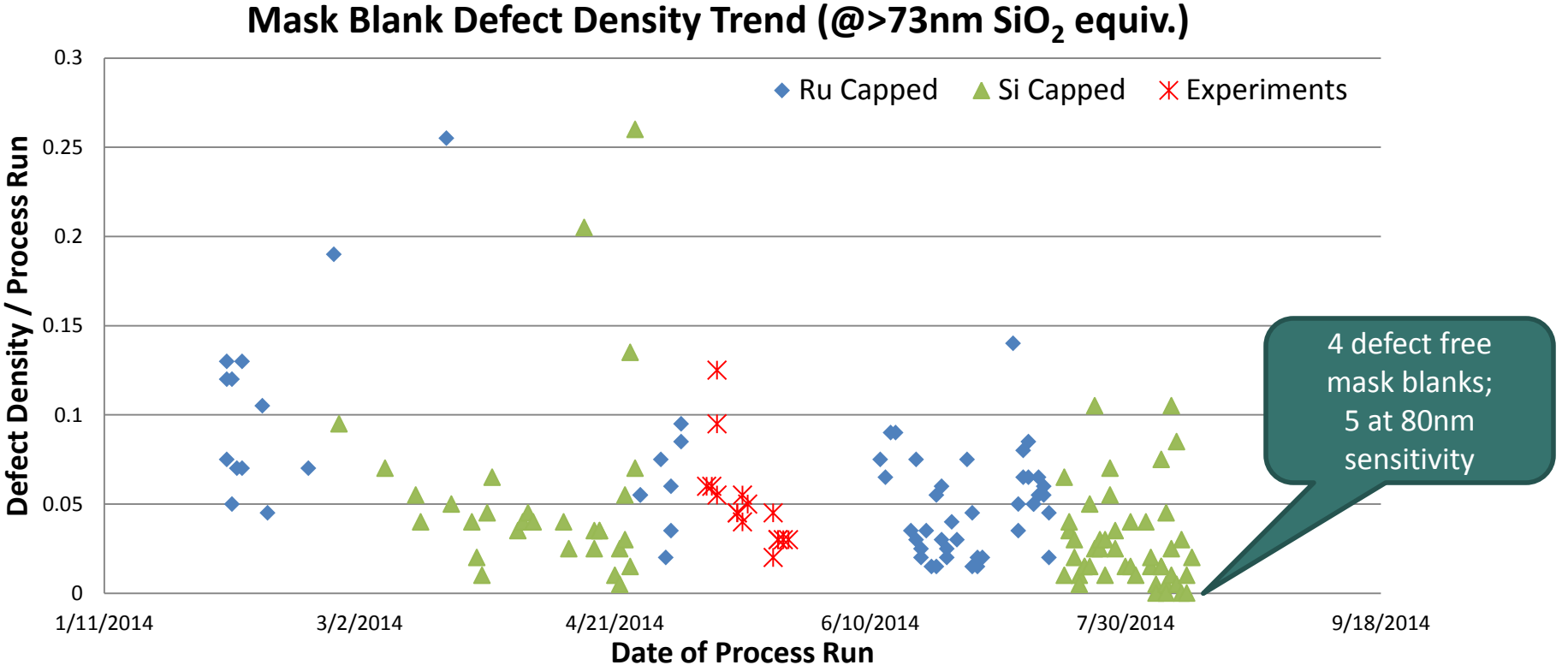
*Mask blanks processed at SEMATECH*




- Defect density of all defects per mask blank
  - Includes substrate and handling defects
  - Data is measured on the LaserTec M1350 over 14.2x14.2cm$^2$ area

# Closer Look at Recent Process Run

*Mask blanks processed at SEMATECH*




- Defect density of total mask blank defects over 14.2x14.2cm$^2$ area
- Best defect results where achieved over the last 48 mask blanks deposited
  - Si capped multilayer deposition
  - Cherry picked substrates
  - New ion optic Design

# Characteristics of Recent Deposition Run

- Defectivity @> 73nm* (mask blank area of 14.2x14.2 $cm^2$)
  - 2.8% of the mask blanks are defect free
  - 58% have single digit defect counts
- However
  - Just 3.6% of the single digit blanks have no defects larger than 80nm*
  - Increases to 6.4% for <10 defects with no defects larger than 100nm*
- Majority of the low defect mask blanks were Si capped
  - Deviation from SEMATECH POR which is Ru capped
  - Issues with sputtering Ru

*** $SiO_2$ equivalent**

# Defect Composition

## *Preliminary analysis*

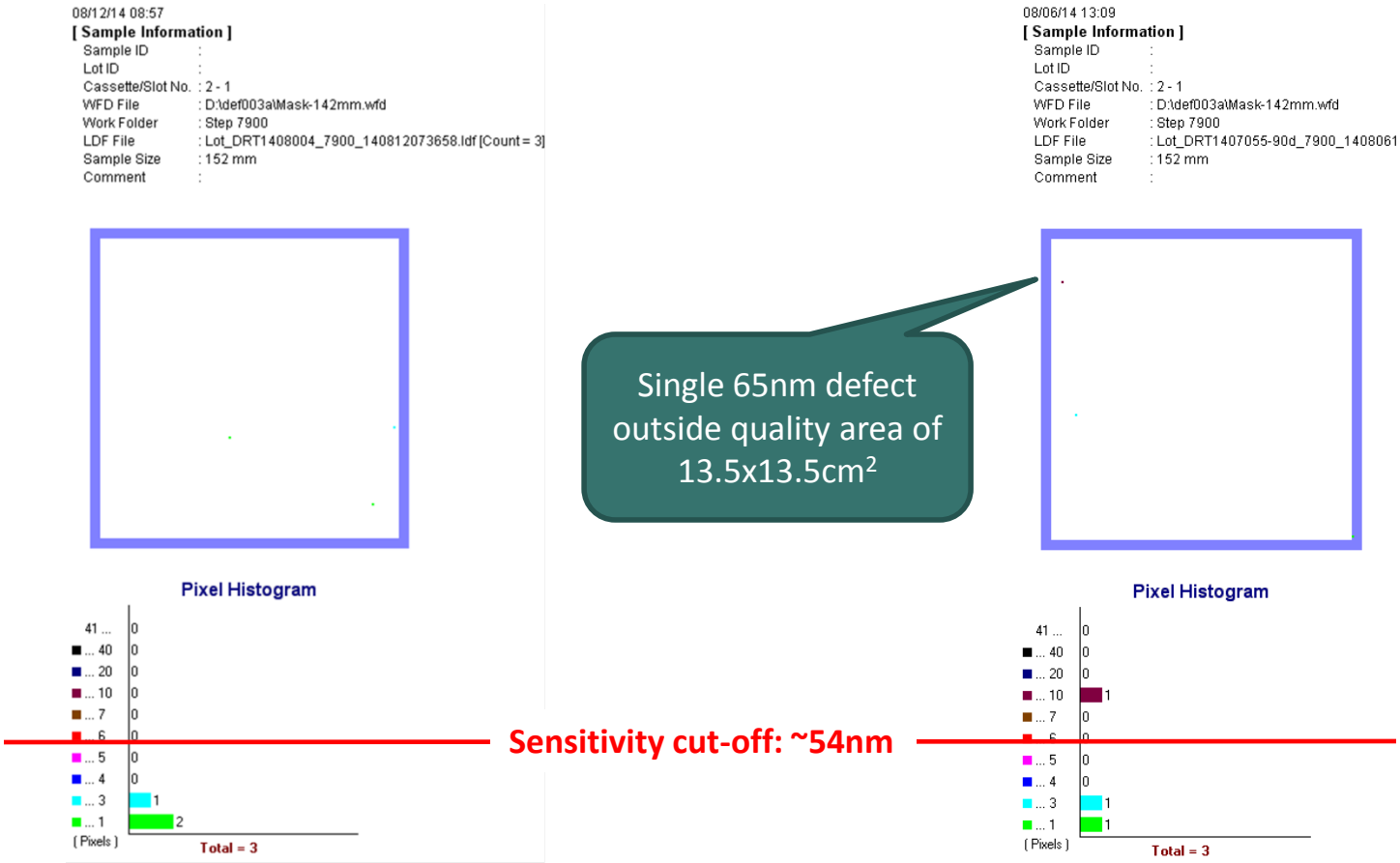
| ADDERS >100nm | M07 | M16 | M17 | M19 | M20 |
|---|---|---|---|---|---|
| **Fe, Ni** | 4% | 6% | 3% | 36% | 12% |
| **Al/AlOx** | 17% | 21% | 13% | 22% | 7% |
| **Ru** | 12% | 2% | 4% | 5% | 0% |
| **Si/SiOx** | 7% | 29% | 17% | 6% | 6% |
| **CA+C** | 5% | 2% | 26% | 6% | 9% |
| **Mo / MoOx** | 0% | 4% | 1% | 0% | 11% |
| **Other: Ti, Mo, Ni, Cu** | 0% | 0% | 1% | 7% | 2% |
| **NO ID** | 54% | 35% | 35% | 17% | 54% |
| **# of blanks** | 11 | 8 | 7 | 35 | 43 |

| ADDERS >100nm | M07 | M16 | M17 | M19 | M20 |
|---|---|---|---|---|---|
| **Fe, Ni** | 0.6 | 1.6 | 0.6 | 4.3 | 0.3 |
| **Al/AlOx** | 2.8 | 5.3 | 2.3 | 2.6 | 0.2 |
| **Ru** | 2.0 | 0.6 | 0.7 | 0.6 | 0.0 |
| **Si/SiOx** | 1.2 | 7.4 | 3.0 | 0.8 | 0.2 |
| **CA+C** | 0.8 | 0.6 | 4.6 | 0.7 | 0.2 |
| **Mo / MoOx** | 0.0 | 1.0 | 0.1 | 0.0 | 0.3 |
| **Other: Ti, Mo, Ni, Cu** | 0.0 | 0.0 | 0.1 | 0.9 | 0.0 |
| **NO ID** | 8.8 | 9.0 | 6.3 | 2.0 | 1.4 |

- ***Preliminary*** analysis is for the recent process run M20
  - Samples still being processed
- Data is on defects > 100nm* in size
- Reduction seen in Al/AlOx, Fe/Ni, Ca/C defects
  - Significant decrease in Al/AlOx defects
  - Likely related to removal of IBD aligner from process flow

*** $SiO_2$ equivalent**

# New Champion Data




- Two Defect-Free Mask Blanks @ 54nm ($SiO_2$ equivalent)
  - 13.5x13.5 $cm^2$

# Process Deviations from POR

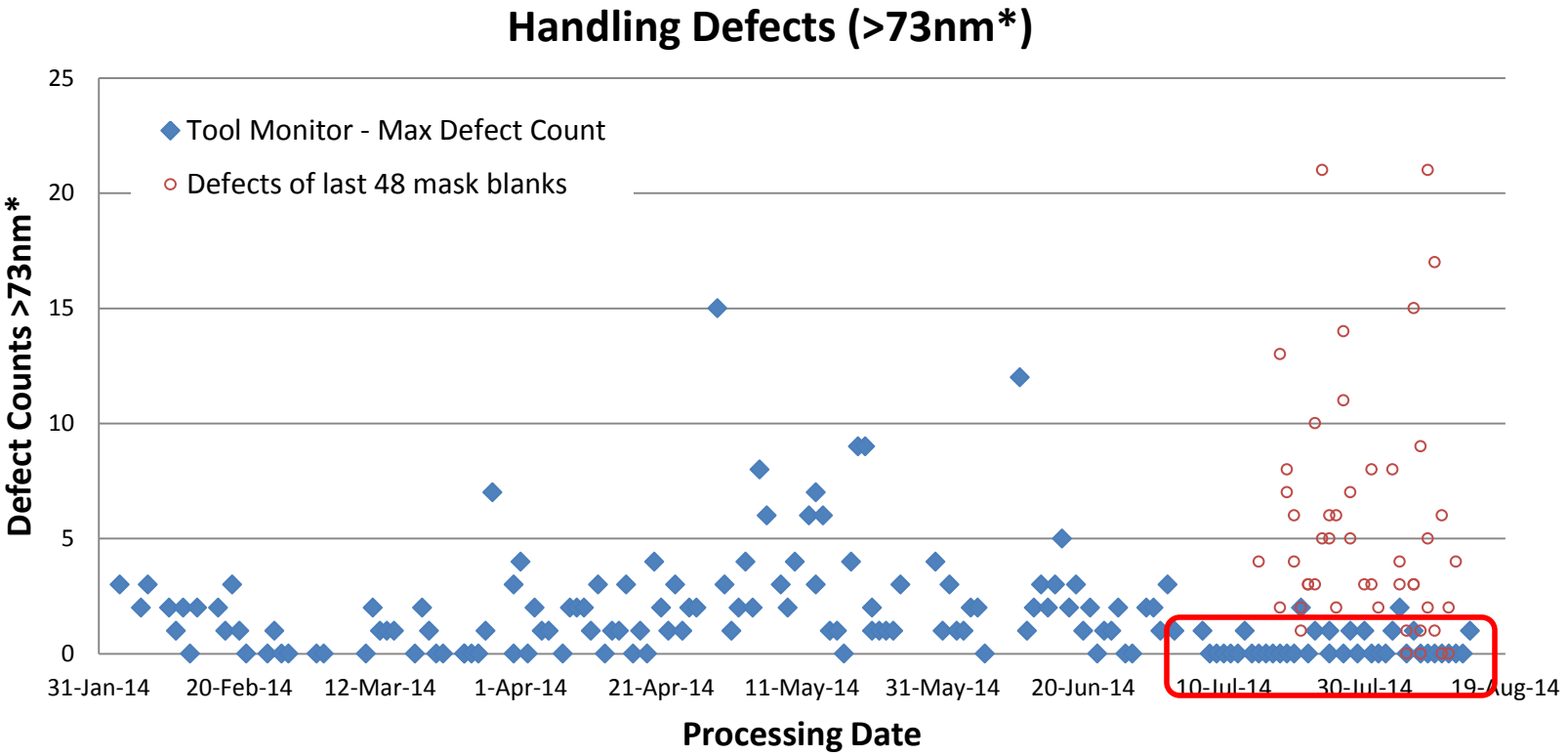
- Over the course of the deposition run there were several adjustments to the POR
  - Process optimization
  - Stricter process control for deposition
  - Modification to IBD tool configuration
  - Substrate management
- For the last 48 mask blanks deposited the improvement in defectivity has a first order correlation to:
  - Substrate management
    - Cherry picking substrates
    - Modification to storage after cleaning
  - Change in the ion optic to elliptical grid design
    - Part of Veeco's Odyssey upgrade package
  - Running Si capped multi-layers
- Correlation analysis on interaction effects has not been completed

# Front-end and Material Handling of IBD Tool

- Material handling of SEMATECH's deposition tools are a known source of defects
  - Routinely adding 5-20(@54nm*) defects
  - Frequent spikes of > 100 adders
- Historically partitioning has not been able to isolate the defect sources
  - New partitioning techniques where introduced
  - Identified the front-end aligner and a chamber feed through as defect sources
- Stricter process controls instituted
  - Tool was not released for deposition if handling monitor had > 3 adder defects
  - Limited deposition to ~1 mask blank per day; manufacturability of IBD process will need to be demonstrated at suppliers

*** $SiO_2$ equivalent**

# Influence of Handling Defects




- Towards end of process run handling defects improved
  - For the most part improvement coincides to improvement of deposition defects
  - All of the mask blanks with <10 total defects and 0 defects @ >80nm* where deposited during this period.

* $SiO_2$ equivalent

# Status of IBD of Mask Blanks

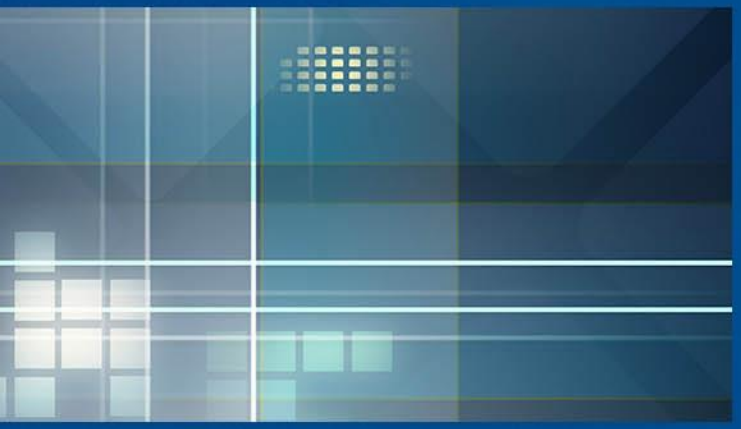
- Technology has demonstrated capability to deposit quality mask blanks
- IBD process has improved but yield is low
  - Sustained quality deposition with low defect counts needs to demonstrated
  - Without impacting capacity
- Veeco is currently exploring a new design of the ion optic and modification to the target turret
  - The new ion optic design was tested during this recent process run
  - All of the 0 defect mask blanks (@ 73nm*) were deposited using the new ion optic
    - Additional process changes may also contributed to achieving these results
- Hurdles also remain in addressing substrate defects
  - Specifically the need for inspection capability with greater sensitivity

*** $SiO_2$ equivalent**

# Summary

- New champion mask blank
  - Defect free at 54nm*
- From the most recent process run
  - Single digit defect counts on over 50% of the mask blank deposited
    - However, yield of quality mask blanks (0 defects @ > 80nm*) was just over 3.5%
  - Improvement of Al/AlOx, Fe/Ni, Ca/C defects
  - Promising results achieved while using the new ion optic design
    - But not definitive
    - Further evaluation of Veeco's upgrade package is required

*** $SiO_2$ equivalent**



# Thank You